

# EXHIBIT E

From: Andrew W. Appel

To: Flavio Komuves

Date: January 24, 2024

Re: Capability of New Jersey's Voting Equipment to handle Office-Block Ballots

I have been asked to assess whether New Jersey's voting equipment can accommodate an "office block" ballot format, in contrast to the row-and-column format that is now used. The answer is yes, the voting equipment used in New Jersey can accommodate office-block voting, and the election management systems can support the preparation of office-block ballots. Furthermore—regarding voting machines that New Jersey might purchase in the future—because the major voting-machine vendors sell in a national market, in which many states already use office-block ballots, new voting systems are designed to accommodate office-block ballots.

**My qualifications:** I am a Professor of Computer Science at Princeton University. I received an A.B. (1981) from Princeton University summa cum laude in Physics, and a PhD (1985) from Carnegie Mellon University in Computer Science. I have over 40 years of experience in computer science, and 18 years of experience studying voting machines and elections. I have testified on election technology before the U.S. House of Representatives (subcommittee on information technology, 2016), the New Jersey legislature (several committees, on several occasions 2005-2018), the Superior Court of New Jersey (Mercer County, 2009; Cumberland County, 2011), the New York State Board of Elections (2019), the Freeholders of Mercer County (2017 and 2019) and Essex County (2019). I have been qualified as an expert witness on voting machines in the Superior Court of New Jersey (Mercer, 2009; Cumberland, 2011) and the U.S. District Court for the Northern District of Georgia (2019). I have published over 140 scientific articles and books, including many papers on computer security and several papers on voting machines, election technology, and election audits. Since 2008 I have published over 90 blog articles<sup>1</sup> about election machinery on freedom-to-tinker.com. I attach my CV as an appendix to this report.

I am being compensated for my time in preparing this report at the rate of \$500 per hour. My compensation is not contingent on reaching or reporting any particular conclusions.

### Office-Block versus Row-and-Column ballots

For an election in which there are several separate contests (such as Governor, Senator, Legislator, Mayor, etc.) each with several candidates, all to be displayed on the same sheet of paper or voting-machine screen, there are different ways that the ballot can be laid out. A civics textbook published in 1909, *Elements of Civil Government* by Alexander Peterman, illustrates the two basic layouts: "office-block", where each contest ("office") is in a single compact block with all the candidates listed; and "row-and-column" in which offices are in the rows and the parties are listed in the columns, or vice versa. I reproduce these illustrations here.<sup>2</sup>

---

<sup>1</sup> See <https://www.cs.princeton.edu/~appel/voting>

<sup>2</sup> From *Elements of Civil Government*, by Alexander L. Peterman, American Book Company, 1909. Accessed at the Library of Congress, <https://www.loc.gov/item/09028732/>.

**PART OF MASSACHUSETTS OFFICIAL BALLOT, NOVEMBER, 1908.**

(821) To vote for a Person, mark a Cross X in the Square at the right of the Party Name, or Political Designation. **X**

GOVERNOR . . . . . Mark ONE.	
JAMES F. CAREY — of Haverhill . . . . . Socialist	
EBEN S. DRAPER — of Hopedale . . . . . Republican	
WALTER J. HOAR — of Worcester . . . . . Socialist Labor	
WILLIAM N. OSGOOD — of Lowell . . . . . Independence League	
JAMES H. VAHEY — of Watertown . . . . . Democratic	
WILLARD O. WYLIE — of Beverly . . . . . Prohibition	

LIEUTENANT GOVERNOR . . . . . Mark ONE.	
CHARLES J. BARTON — of Melrose . . . . . Democratic	
JOAO CLAUDINO — of New Bedford . . . . . Socialist Labor	
LOUIS A. FROTHINGHAM — of Boston . . . . . Republican	
JOHN HALL, Jr. — of West Springfield . . . . . Socialist	
ROBERT J. MCCARTNEY — of Kingston . . . . . Independence League	
FRANK N. RAND — of Haverhill . . . . . Prohibition	

To vote for a Person, mark a Cross X in the Square at the right of the Party Name, or Political Designation. **X**

CONGRESSMAN — Tenth District . . . . . Mark ONE.	
J. MITCHELL GALVIN — of Boston . . . . . Republican	
CHARLES J. KIDNEY — of Boston . . . . . Independence League	
JOSEPH F. O'CONNELL — of Boston . . . . . Democratic	
HAZARD STEVENS — of Boston . . . . . Free Trader	

COUNCILLOR — Second District . . . . . Mark ONE.	
ALBION F. BEMIS — of Brookline . . . . . Republican	
CHARLES G. KIDDER — of Taunton . . . . . Independence League	





  

SENATOR — First Norfolk District . . . . . Mark ONE.	
JAMES E. FOLEY — of Randolph . . . . . Democratic	
JOHN J. GALLAGHER — of Hyde Park . . . . . Socialist	
EUGENE C. HULTMAN — of Quincy . . . . . Republican	

Office-block ballot from Massachusetts, 1908. Peterman, p. 186

**PART OF INDIANA STATE TICKET. NOVEMBER, 1908.**

(421)

 <b>Democratic Ticket.</b>		 <b>Republican Ticket.</b>		 <b>Prohibition Ticket.</b>		 <b>People's Party Ticket.</b>	
DEM.	For Governor, THOMAS R. MARSHALL.	REP.	For Governor, JAMES E. WATSON.	PROH.	For Governor, SUMNER W. HAYNES.	PEOP.	For Governor, FRED J. S. ROBINSON.
DEM.	For Lieutenant-Governor, FRANK J. HALL.	REP.	For Lieutenant-Governor, FREMONT GOODWINE.	PROH.	For Lieutenant-Governor, ABRAHAM HUNTSINGER.	PEOP.	For Lieutenant-Governor, ORLANDO L. ROSS.
DEM.	For Secretary of State, JAMES F. COX.	REP.	For Secretary of State, FRED A. SIMS.	PROH.	For Secretary of State, WILLIAM H. HILL.	PEOP.	For Secretary of State, RICHARD BONEWITZ.
DEM.	For Auditor of State, MARION BAILEY.	REP.	For Auditor of State, JOHN C. BILLHEIMER.	PROH.	For Auditor of State, HENRY COONS.	PEOP.	For Auditor of State, JAMES S. REEVES.
DEM.	For Treasurer of State, JOHN LSENBAOER.	REP.	For Treasurer of State, OSCAR RADLEY.	PROH.	For Treasurer of State, WILLIAM H. CROWDER.	PEOP.	For Treasurer of State, AARON McDONALD.

Row-and-column ballot from Indiana, 1908. Peterman, p. 187

**Mechanical lever voting machines**

Mechanical voting machines were invented just before 1900, and during much of the 20<sup>th</sup> century, some New Jersey counties were using mechanical lever-action voting machines. In such a machine, each small lever is directly connected to an odometer-like counter. A mechanical interlock prevents overvotes (that is, voting for more than one candidate in the same contest) by preventing more than one lever in the same row from being turned. This interlock is fairly simple to implement in a row-and-columns layout, but would be more complex in an office-block format. Hence, the use of mechanical machines necessitated a rows-and-columns layout. Computerized voting machines, such as all the ones now in use in New Jersey, are not subject to this mechanical limitation.

### Voting Equipment Used in New Jersey

Each New Jersey county purchases its own voting machines and EMS (election management system), and may choose from any equipment certified by the Secretary of State (based on advice from a statutory voting-machine examination committee). At present, the counties use the following equipment as shown in the following table.<sup>3</sup>

#### Polling place voting machines used in New Jersey

Type of Equipment	Make	Model
Hand-Fed Optical Scanner	Dominion	ImageCast Precinct
Hand-Fed Optical Scanner	ES&S	DS200
Hand-Fed Optical Scanner	ES&S	DS300
Hybrid Optical Scan/DRE	Dominion	ImageCast Precinct ATI
Ballot Marking Device	Dominion	ImageCast X BMD
Ballot Marking Device	ES&S	ExpressVote
Hybrid BMD/Tabulator	ES&S	ExpressVote XL
DRE-Push Button	Sequoia (Dominion)	AVC Advantage
DRE-Touchscreen	Dominion	ImageCast X DRE

#### Mail ballot/absentee equipment used in New Jersey

Type of Equipment	Make	Model
Batch-Fed Optical Scanner	Dominion	ImageCast Central
Batch-Fed Optical Scanner	ES&S	DS450
Batch-Fed Optical Scanner	ES&S	DS850
Batch-Fed Optical Scanner	ES&S	DS950
Remote Ballot Marking System	Democracy Live	OmniBallot Online

<sup>3</sup> Source of this data: Verified Voting Foundation, <https://verifiedvoting.org/verifier> I am on the Board of Technical Advisers of Verified Voting; I have used this database many times over the past 15 years, and have found it to be reliable.

## Analysis

New Jersey counties use voting machines from four different manufacturers' product lines: Dominion, ES&S, Sequoia, and Democracy Live. I will assess each product line individually.

**Dominion:** Several NJ counties (Bergen, Burlington, Cumberland, Essex, Mercer, Salem, Somerset) use Dominion Voting Systems's suite of "ImageCast" equipment first introduced in about 2009. These are relatively modern designs, all compatible with each other, marketed and used in many states, including some states that use office-block voting. For example, a sample ballot from Armstrong County, PA (for the November 2023 municipal general election) shows an office-block ballot.<sup>4</sup> Armstrong County uses the same line of Dominion equipment (ImageCast Precinct, ImageCast X BMD) as New Jersey does.

**ES&S DS series:** Many NJ counties (Atlantic, Bergen, Camden, Cape May, Gloucester, Hudson, Hunterdon, Middlesex, Monmouth, Morris, Ocean, Passaic, Somerset, Sussex, Union, Warren) use Election Systems and Software's "DS" suite of equipment first introduced in approximately 2010: polling-place optical scanners DS200 and DS300, central-count optical scanners DS450, DS850, DS950, and ballot-marking devices ExpressVote and ExpressVote XL. These voting machines are used in many states, including those that use office-block ballot layouts. For example, a sample ballot from McPherson County, South Dakota has an office-block layout.<sup>5</sup>

**The ES&S ExpressVote** is a small-screen touchscreen ballot-marking device. It presents only one contest at a time to the voter, that is, one contest per screen. Therefore it most naturally supports the office-block format.

**The ES&S ExpressVote XL** is a full-face touchscreen all-in-one (ballot-marking and ballot printing) voting machine. Although no state currently using the ExpressVote XL does so with an office-block format, several pieces of evidence suggest that it is possible:

- ES&S's brochure for this machine says it "Supports many layout options, including grid style for party voting in rows or columns. This configuration can easily be managed by jurisdictions, allowing for the most efficient use of the ExpressVote XL screen."<sup>6</sup>
- The State of Washington, which uses office-block ballots generally, approved the ExpressVote XL as a ballot-marking device,<sup>7</sup> which suggests that there is no limitation to a row-and-column format.
- The ExpressVote XL has the capability to present contests on more than one screen, as the ExpressVote does, so it also could support an office-block layout in that manner.

<sup>4</sup> <https://co.armstrong.pa.us/images/departments/votersregistration/sampleballots/ballots-fall/ballots-municipal/ELECTION%20DAY%20Applewold%20Borough-ID%204.pdf> accessed December 26, 2023.

<sup>5</sup> <https://mcpherson.sdcountries.org/files/2020/09/2020-General-Election-SAMPLE-Ballot.pdf> accessed December 26, 2023.

<sup>6</sup> [https://www.essvote.com/storage/2021/10/ExpressVote\\_XL-One-Sheet.pdf](https://www.essvote.com/storage/2021/10/ExpressVote_XL-One-Sheet.pdf) accessed December 26, 2023.

<sup>7</sup> [https://www.sos.wa.gov/sites/default/files/2023-12/ES%26S\\_EVS\\_6.4.0.0\\_staff\\_report.pdf](https://www.sos.wa.gov/sites/default/files/2023-12/ES%26S_EVS_6.4.0.0_staff_report.pdf) Report of the Secretary of State on the examination of Election Systems & Software EVS 6.4.0.0, November 2023.

- The Pro V&V test report<sup>8</sup> on the ExpressVote XL lists several limitations: “does not offer open primary support, does not support Massachusetts Group Vote, does not support Universal Primary Contest, does not support Multiple Target Cross Endorsement,” and so on, but the report does not indicate (in its discussion of the ExpressVote XL) any limitation regarding office-block contests.

**Sequoia:** Many counties adopted the Sequoia AVC Advantage voting machine between 2000 and 2004. Dominion now services this machine, but it is not part of their ImageCast product line that I discuss above. Only Burlington County still uses this machine, and only in election-day precincts (in early voting, Burlington uses Dominion’s ImageCast product line). I studied this machine intensely in 2008.<sup>9</sup> I know of no reason that it could not support an office-block ballot layout. This machine is obsolete: it was designed in 1988, it does not produce a paper trail (voter-verifiable paper ballot) and thus cannot be used (by NJ statute) in early vote centers; it is difficult to get parts for. By 2008, all but two of New Jersey’s counties were using it, but now only Burlington county uses it.

**Democracy Live OmniBallot** is an online ballot return system that some New Jersey counties allow overseas military voters and voters with disabilities to use. Democracy Live’s demonstration video shows this system being used with an office-block ballot.

## Ballot Preparation

Before each election, New Jersey counties must prepare “Ballot Definition Files”, computer files that specify which are the contests and questions in that election, and who are the candidates in those contests. This task is performed using an Election Management System (EMS), which is software provided by the voting-machine vendor, that runs on an ordinary desktop or laptop computer. From the Ballot Definition Files, also using the EMS, PDF files for paper ballots are produced. Also produced, again using the EMS, are files written to removable media, via which the information about the election is transferred to the voting machines. These tasks may be performed, using the EMS, by county employees or by private companies contracted by the counties to assist in elections.

Each election-equipment vendor, such as Dominion or ES&S, provides EMS software compatible with its own equipment. This EMS software is standard, in the sense that the same software is used in several states. To the extent that the Dominion and ES&S voting equipment that I discussed above, under the heading “Analysis”, supports office-block ballots, the corresponding EMS, already supplied by the vendor to New Jersey counties, will also support office-block ballots. It is my opinion that the work or effort needed to prepare office-block ballots, using the same EMS, will not be significantly different from the work or effort needed to prepare row-and-column ballots.

The U.S. Election Assistance Commission (EAC) certifies election equipment, based on reports from accredited Voting Systems Testing Labs (VSTLs) that the equipment actually works. Part of this testing is to make sure that the EMS can prepare ballots. Whether or not EAC certification is generally required by New Jersey statutes, I have observed (over the past 15 years) that New

---

<sup>8</sup> Test Report for EAC VVSG 1.0 Certification Testing Election Systems & Software (ES&S) Voting System (EVS) 6.1.0.0, by Pro V&V, Inc., November 2019. This report was used by the U.S. Election Assistance Commission as the basis for certifying the ExpressVote XL.

[https://www.eac.gov/sites/default/files/voting\\_system/files/ESS\\_EVS6100\\_Test\\_Report\\_Rev\\_02.pdf](https://www.eac.gov/sites/default/files/voting_system/files/ESS_EVS6100_Test_Report_Rev_02.pdf)

<sup>9</sup> See Insecurities and Inaccuracies of the Sequoia AVC Advantage 9.00H DRE Voting Machine, by Andrew W. Appel, Maia Ginsburg, Harri Hursti, Brian W. Kernighan, Christopher D. Richards, and Gang Tan, October 2008. <https://www.cs.princeton.edu/~appel/papers/advantage-insecurities-redacted.pdf>

Jersey's Secretary of State relies on EAC certification of a voting system before approving it for use in New Jersey. Therefore one can expect that not only these Dominion and ES&S voting systems, and their accompanying EMS software, but also any voting machines purchased in the future from these and other vendors (and their accompanying EMS), will accommodate office-block ballots.

## Conclusion

New Jersey counties use these product lines of voting machines, each product line with a corresponding EMS (election management system) software:

Dominion ImageCast, ES&S DS series, ES&S ExpressVote, and Democracy Live Omniballot, all of which can definitely support an office-block ballot and are used with office-block formats in other states.

ES&S ExpressVote XL, for which there is evidence that it can support an office-block ballot but which has not yet been used that way in any jurisdiction.

Sequoia AVC Advantage, for which there is no evidence that it cannot support an office-block ballot, which is obsolete, which is difficult to maintain or get parts for, which (unlike every other voting machine used in New Jersey polling places) has no voter-verifiable paper trail, which (for these reasons) all but one New Jersey county abandoned and which (for these reasons) is unlikely to be used for much longer in any county.

Signed on \_\_ January 24, 2024\_\_

A handwritten signature in blue ink, appearing to read "Andrew Appel", written over a horizontal line.

Andrew W. Appel